PB82-169210

# Storm and Combined Sewers
# Part of the Treatment Process

(U.S.) Municipal Environmental Research Lab.
Edison, NJ

1982

U.S. Department of Commerce
National Technical Information Service
NTIS.

**TECHNICAL REPORT DATA**
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| | | |
|---|---|---|
| 1. REPORT NO. EPA-600/J-82-126 | 2. Journal Article | 3. PB82-169210 |
| 4. TITLE AND SUBTITLE "STORM AND COMBINED SEWERS: PART OF THE TREATMENT PROCESS" | | 5. REPORT DATE February 1982 |
| | | 6. PERFORMING ORGANIZATION CODE 054128 |
| 7. AUTHOR(S) Richard Field | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Storm and Combined Sewer Section Woodbridge Avenue, Building 10 Edison, New Jersey 08837 | | 10. PROGRAM ELEMENT NO. |
| | | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268 | | 13. TYPE OF REPORT AND PERIOD COVERED Journal Article |
| | | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

WATER/Engineering & Management, January, 1982 issue - pp. 34-36 & 39.

16. ABSTRACT

The use of existing collection systems as part of the municipal wastewater treatment process has been clearly demonstrated by the U.S. Environmental Protection Agency Municipal Environmental Research Laboratory's Storm and Combined Sewer (SCS) Program. Some of the topics studied relate to collection systems, and a review of these provides insight into the management of collection systems for the dual purposes of drainage and pollution control. Maintenance and management of collection systems are absolutely necessary to achieve cost-effective combined sewer overflow (CSO) pollution control.

Specific topics include: Inspection and Maintenance, Catchbasins, New Sewer Design, Sewer Flushing, Polymer Injection, and Infiltration/Inflow Controls, Upstream Storage/Attenuation, Flow Routing and In-Pipe Storage, New Types of Flow Regulators, and The Duck Bill Tide Gate.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| | | |

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |

EPA-600/J-82-126
Journal Article

# Storm and Combined Sewers: Part of the Treatment Process

by Richard Field

That there is tremendous opportunity to use existing collection systems as part of the municipal wastewater treatment process has been clearly demonstrated by the U.S. EPA Municipal Environmental Research Laboratory's Storm and Combined Sewer (SCS) Program, now more than 15 years old. Some of the topics studied relate to collection systems, and a review of these provides insight into the management of collection systems for the dual purposes of drainage and pollution control. Maintenance and management of collection systems are absolutely necessary to achieve cost-effective combined sewer overflow pollution control.

It was originally believed that the best answer to abatement of the combined sewer overflow (CSO) pollution problem was to eliminate combined sewers by constructing separate storm and sanitary sewers. More recently, in light of the costs and disruption involved in separating combined sewers, emphasis is being placed on alternatives to sewer separation. A national sewer separation project would cost about $100 billion, or three times the cost of alternative control measures.

**About the Author**
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There is clear evidence that urban stormwater runoff itself can be a significant source of stream pollution, and sewer separation would not cope with this pollutant load.

### Inspection and Maintenance

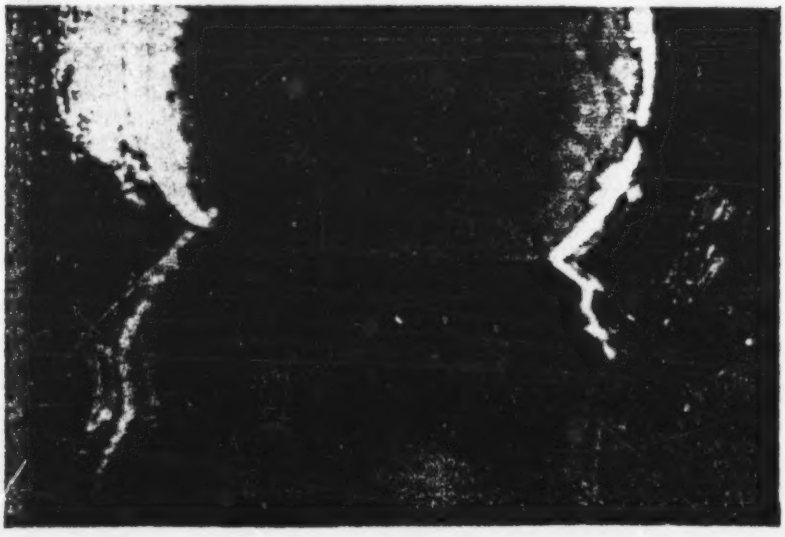
Improved sewer inspection and maintenance is absolutely essential in a total system approach to municipal water pollution control. Premature overflows and backwater intrusions during dry as well as wet weather caused by malfunctioning regulators and tide gates, improper diversion settings, and partially filled interceptors and sewers will thus be alleviated. The resulting abatement obtained is an ancillary benefit of effective system maintenance, and the approval of policies to enforce it is a worthwhile goal for regulatory agencies.

### Catchbasins

Historically, the role of catchbasins has been to minimize sewer clogging by trapping coarse debris and to reduce odor emanations from low-velocity sewers by providing a water seal. A few years ago a project was undertaken to assess the value of catchbasins as they are presently designed and maintained. Optimized basin configuration, design and maintenance for removing solids before sewer system entry was also investigated.

In a test conducted in the West Roxbury section of Boston, three catchbasins were cleaned and subsequently monitored during seven runoff events. They were shown to be potentially quite effective for solids reduction (60–97 percent). Catchbasin removals of associated pollutants such as chemical oxygen demand (COD) and biochemical oxygen demand (BOD) were also significant (10–56 percent and 54–88 percent, respectively). Maintaining the effectiveness of catchbasins for pollutant removal requires more frequent cleaning than is usually carried out—probably twice a year depending upon conditions. The increased cost of cleaning must be considered in assessing their practicality for pollution control. A cost effectiveness analysis using the actual field data from West Roxbury is being conducted. Preliminary results indicate biannual catchbasin cleaning is cost effective for CSO pollution control when integrated with downstream treatment.

Figure 1a. Insituform Liner in a 12-in. Sewer.



### New Sewer Design

Traditional storm and combined sewer design is based on the precepts that:

1. Storm generated flows do not contain pollutants;
2. Self-cleansing velocities are obtained during storms; and
3. Old economic principles which only considered the costs for conventional flood control and drainage prevail.

Consequently, sewers were designed for high flow conditions. But how often does maximum flow occur? Once in five years? Once in ten years? Once in 25 years? Therefore, dry-weather loads deposit. Solids deposition in sewer lines has always been a plague to effective maintenance. Recently, the significance of such loads as a major contribution to first flush pollution has been recognized.

New design concepts are needed which take into account pollution abatement. The costs of designing sewers for both flood control and pollution abatement are justified under new economic principles which evaluate alternatives such as steeper sewers with more pumping and special cross-sectional shapes both to obtain minimum solids carrying velocity at low dry-weather flows in order to avoid deposition versus the cost for control of the added first flush from old design concepts which allow dry weather de-

position. A project was undertaken to study new sewer designs based upon maintaining adequate low flow solids carrying velocity to alleviate sewer sedimentation, and resultant first flush pollution and premature bypassing during storms. The study concluded that feasible methods of controlling first-flush pollution do exist. They include increasing conduit slopes and providing cunette sections or other pipe shapes that maintain a high velocity during low flow periods. These alternatives are directed toward minimizing pipeline accumulation of solids to reduce downstream treatment needs.

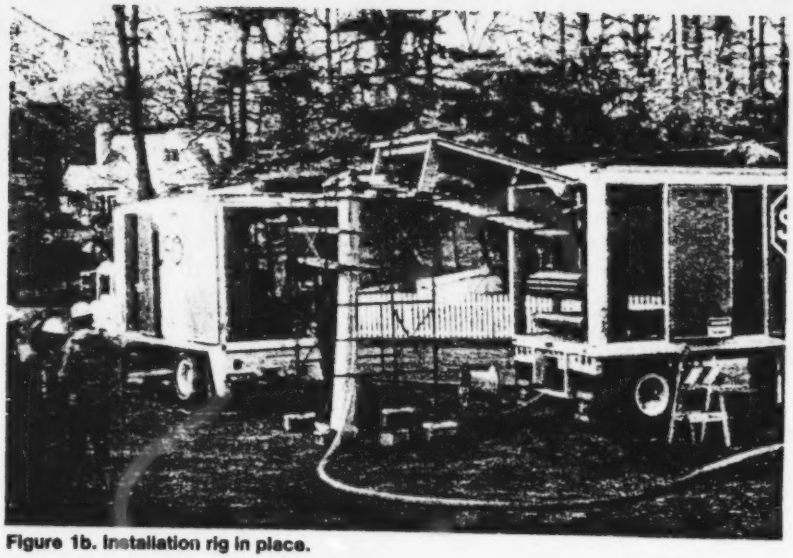


**Figure 1b. Installation rig in place.**

In a project conducted in Elizabeth, New Jersey the following types of system designs were compared: separate storm and sanitary, conventional combined, and advanced combined with varying amounts of in-pipe and/or satellite storage and controlled flow routing. Basically, the new method is the old combined sewer incorporating in-line storage for wet-weather flow. The cost-effectiveness comparison was based on achieving a desired effluent quality assuming a new sewer system.

The study found that providing additional storage in a new combined sewer system should result in the least-cost system for pollution control. This storage can be provided by enlarging the size of the upstream sewer reaches if site restrictions result in costly satellite storage basins. The study also recommended that combined sewers should be considered for new development in urban areas with relatively high imperviousness that these sewers should be designed to maintain flushing velocity for dry weather flows. Also, upstream storage in the collection system (either in-pipe or satellite) should be required in new combined systems and, where practical, for the improvement of existing systems.

**Sewer Flushing**

Sewer flushing is an effective means for substantially reducing solids deposited during dry weather in small-diameter combined sewer laterals. This alleviates wet-weather CSO pollution and reduces downstream treatment requirements. Roughly 35 to 45 percent removal of organics was demonstrated for segment lengths greater than 1,000 ft.

**Polymer Injection**

Polymer slurry injection into sewage has resulted in significant hydraulic friction reductions; hence, a temporary increase (up to 144 percent reported) in line capacities is achieved. This increase is significant in stormwater applications because the sewer surcharges associated with excess wet-weather flows are generally of short duration; thus, a marginally inadequate line can be bolstered by polymer injections at critical periods. In effect, this increases the overall treatment efficiency by allowing more of the flow to reach the treatment plant, while flooding from sewer surcharges is decreased. Polymer concentrations of between 35 and 100 mg/l decreased flow resistance sufficiently to eliminate surcharges of more than 6 ft.

**Infiltration/Inflow Controls**

The major objectives of *inflow reduction* techniques are to maximize the collection and treatment capabilities and to prevent downstream overflow pollution by limiting extraneous sources.

The Springfield, Illinois Sanitary District, in a concerted program to remove improper connections and extraneous inflows to its sewer system, was able to substantially reduce downspout connections. Besides improving the use of the sewer system, the project eliminated the numerous public complaints of basement flooding. The district has estimated that the expense of removing the roof leaders will be fully returned within 16 months by virtue of reduced operation and maintenance.

*Infiltration control* by sewer system rehabilitation is only partially effective because of migrating leakage and the difficulties of breaking house connections. New network evaluation and corrective procedures to detect potential for migrating leaks, and more feasible ways (other than excavating) to control the house lateral infiltration problem are being investigated.

Originally developed in Great Britain in the early 1970s, *Insituform* is a relatively new method for sewer rehabilitation in the U.S. It is being demonstrated in Northbrook, Illinois and Hagerstown, Maryland as part of the SCS Program. The objectives of the projects are to establish the feasibility and cost-effectiveness of the process for rehabilitating deteriorated sanitary sewers. Approximately 8,300 ft of sewer pipe, ranging in size from 8–27 in., are involved in these tests.

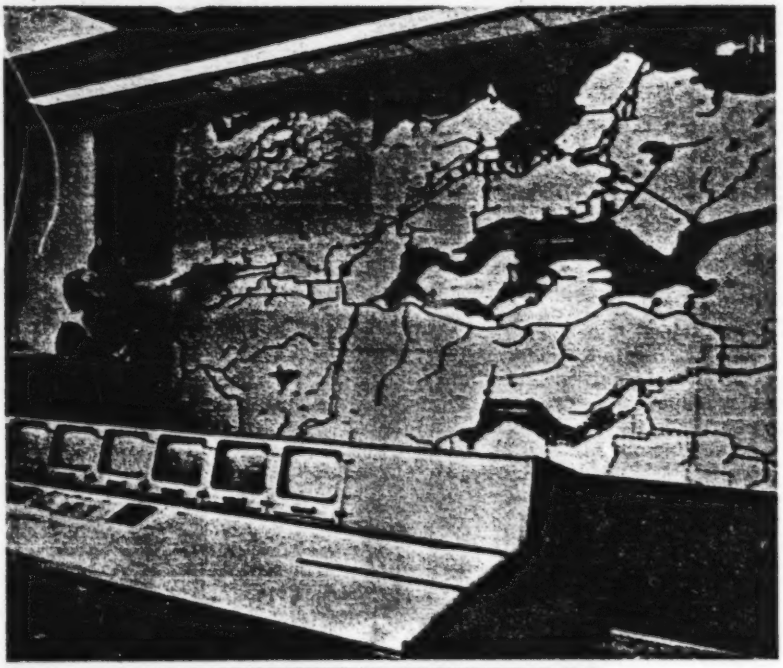
The process makes use of a polyester fiber felt tubing, sealed at the downstream end to form an elongated bag, lined on one side with polyurethane and fully impregnated with a liquid thermal-setting resin. The method literally creates a new pipe within the damaged original and provides its own structural integrity. Upon insertion, the material is pliable and the resin is a viscous liquid. This allows the product to fill cracks, bridge gaps, surmount rubble and even turn 45 degree angles. **Fig. 1a** shows an Insituform line in a 12 in. sewer. Since it molds itself against the pipe wall and the lining itself is relatively thin, there is virtually no flow-through area reduction. It is claimed that its smooth surface will improve flow capacity by reducing friction. Its chemical makeup resists corrosion which can often lead to infiltration problems. An installation fea-

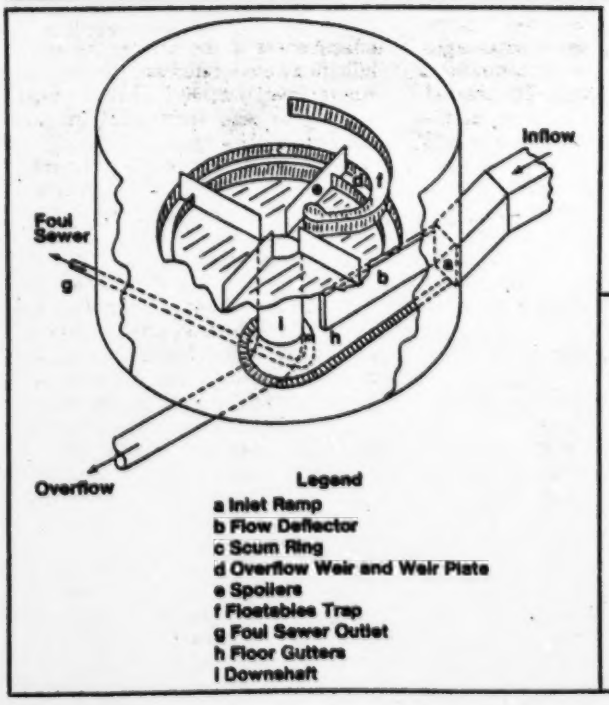
ture of Insituform is that insertion is through existing manholes rather than by excavation (Fig. 1b).

Concrete pipe is widely used in sewer construction. Research conducted by the SCS Program found that *pipe impregnation* with sulfur reduced the permeability of the concrete. Thus, corrosive soil chemicals and sulfuric acid produced by septicity were inhibited from reacting with the concrete and its steel reinforcing rods. Pipe deterioration leading to infiltration and structural failure is significantly reduced.

It was also established that nonreinforced pipe impregnated with sulfur approached the strength of steel reinforced pipe. The dramatic strength improvement, coupled with the improved corrosion resistance, points to the possibility that sulfur impregnation will be used in future installations, with savings in material cost.

Control of infiltration should begin during sewer pipe installation. Better construction materials and proper installation techniques are necessary. *Trenchless sewer* construction by plowing has been successfully demonstrated in a project conducted at South Bethany Beach, Delaware. The technique consists of plowing in solvent welded polyvinyl chloride (PVC) pipe on a grade established and controlled by a laser unit. (The installation is similar to the technique of plowing in underground cables.) This resulted in a system with virtually little, if any, infiltration due to the high corrosion resistance of the pipe. Since plowing in is done in 600 ft lengths, there are few joints, and they are chemically welded.





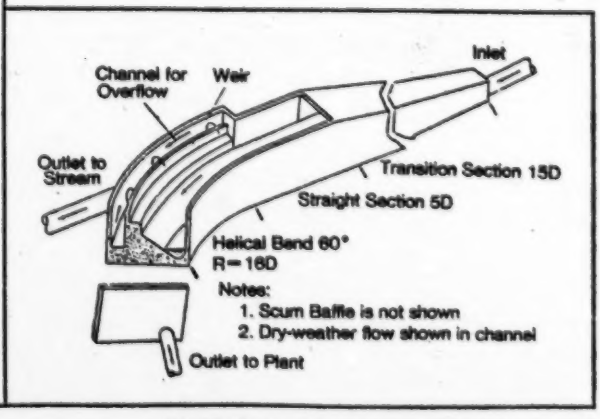




**Figure 2. (above) Stormwater Routing Control Center, Seattle, Washington.**

**Figure 3. (left) Isometric View of Swirl Regulator/Concentrator.**

**Figure 4. (below) Isometric View of Helical Bend Regulator.**

### Upstream Storage/Attenuation

*Surface ponding* is the most common form of detention used by developers. Apparent economic benefits of surface ponding for flood protection are derived from the savings over a conventional sewer project. The utilization of depression storage by flooding curblines, right-of-ways and lawn areas for brief periods reduces downstream flooding which usually has more of a negative impact than upstream flooding and also reduces the need for larger pipes.

A project in Cleveland, Ohio is demonstrating how controlling the rate of stored stormwater entering the sewerage system alleviates basement flooding and overflow pollution. The flowrate is regulated by a *hydrobrake* internal energy dissipator. This small device, located at the downstream end of an underground stormwater tank, delivers a virtually constant discharge rate regardless of head variations. No moving parts or external energy sources are required.

### Flow Routing and In-Pipe Storage

Another collection system control method is in-sewer or in-pipe storage

(continued from page 36)

and routing of storm flows to make maximum use of existing interceptors and sewer line capacity to minimize overflows and maximize system treatment. The general approach comprises remote monitoring of rainfall, flow levels, and sometimes quality, at selected locations together with a centrally computerized console for positive regulation. This concept has proved to be effective in Detroit and Seattle. Fig. 2 shows Seattle's stormwater routing control center.

### New Types of Flow Regulators

There are roughly 18,000 CSO points or regulators in this country. New types of regulators have been developed by the SCS Program for more effective overflow control.

Quantitative and qualitative control, or the 2-Q approach to overflow control, is very much a part of the regulatory picture of today. Both the dual-functioning *swirl* (**Fig. 3**) and *helical bend regulator/concentrators* (**Fig. 4**) have shown outstanding potential for providing 2-Q control of discharges to receiving waters for the first time in this country.

Solids separation is caused by the inertia differential which results from a circular or secondary path of travel. The flow is separated into a large volume of clear overflow and a concentrated low volume of waste that is intercepted for treatment at the wastewater treatment plant. In addition to regulation of combined sewer flow, these devices provide high-rate preliminary treatment for heavy solids removal. Major attributes of the swirl concentrator are relatively constant treatment efficiency over a wide range of flow rates, its simple annular-shaped construction, and the absence of mechanical parts which use energy. Swirl and helical bend regulator/concentrators have been modeled and in several cases, demonstrated. The data in the **Table** below indicates the swirl regulator/concentrator achieved an average suspended solids (SS) mass loading net removal of 19 percent over conventional regulators during a demonstration in Syracuse, New York.

If there is a concern about separate stormwater pollution, swirls and helicals similar to the combined sewer overflow regulator variety can be installed on separate storm drains before discharge. The resultant concentrate can be stored in relatively small tanks since its flow is only a few percent of the total. Stored concentrate can later be directed to the sanitary sewer for subsequent treatment during low-flow or dry-weather periods. This method might be cheaper in certain cases than building huge holding reservoirs, and it offers a feasible approach to the treatment of separately sewered urban stormwater.

The *fluidic regulator* offers most of the flexibility and performance of the dynamic regulator, yet retains the low cost, simplicity, reliability of operation, and ease of maintenance of the static concept. The unit, mounted in the main stream, has no moving parts and permanently open flow passages. Construction is from standard, non-corrosive materials such as concrete and stainless steel. These characteristics render the fluidic regulator minimally susceptible to common problems such as blockages, corrosion, fouling, jamming, etc. Another advantage is that it is self-powered, deriving its energy directly from the sewage flow.

**Table**
**Swirl Regulator/Concentrator vs. Conventional Regulator**

| | Swirl Regulator/Concentrator Average SS per storm (mg/l) | | | Mass Loading (kg) | | | Conventional Regulator (hypothetical) Mass Loading (kg) | | | Swirl Net Removal Benefit (%)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Storm # | Inf. | Eff. | (%) Rem.* | Inf. | Eff. | (%) Rem.* | Inf. | Underflow | (%) Rem.† | |
| 2-1974 | 535 | 345 | 36 | 374 | 179 | 52 | 374 | 101 | 27 | 25 |
| 3-1974 | 182 | 141 | 23 | 69 | 34 | 51 | 69 | 33 | 48 | 3 |
| 7-1974 | 110 | 90 | 18 | 93 | 61 | 34 | 93 | 20 | 22 | 12 |
| 10-1974 | 230 | 164 | 29 | 256 | 134 | 48 | 256 | 49 | 19 | 29 |
| 14-1974 | 159 | 123 | 23 | 99 | 57 | 42 | 99 | 26 | 26 | 16 |
| 1-1975 | 374 | 167 | 55 | 103 | 24 | 77 | 103 | 66 | 64 | 13 |
| 2-1975 | 342 | 202 | 41 | 463 | 167 | 64 | 463 | 170 | 37 | 27 |
| 6-1975 | 342 | 259 | 24 | 112 | 62 | 45 | 112 | 31 | 28 | 17 |
| 12-1975 | 291 | 232 | 20 | 250 | 168 | 33 | 250 | 48 | 19 | 14 |
| 14-1975 | 121 | 81 | 33 | 83 | 48 | 42 | 83 | 14 | 17 | 25 |
| 15-1975 | 115 | 55 | 52 | 117 | 21 | 82 | 117 | 72 | 62 | 20 |

** Data reflecting negative SS removals at tail end of storms not included.*
*† For the conventional regulator removal calculation, it is assumed that the SS concentration of the foul underflow equals the SS concentration of the inflow.*
*** Calculated by subtracting the hypothetical percent SS removals in a conventional regulator, from the percent SS removals in a swirl regulator/concentrator.*

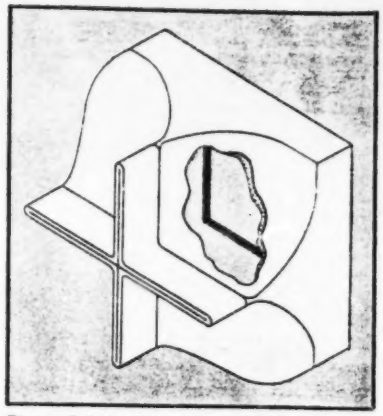


**Figure 5. Isometric View of Rubber "Duck Bill" Tide Gate.**

The cost of refitting a fluidic regulator was estimated to be 40 percent more and 50 percent less than retrofitting a conventional static and a conventional dynamic regulator, respectively. A new installation could cost 10 percent more than a conventional static unit. But maintenance would be less.

The *hydrobrake* discussed earlier as a regulator for stored effluent can also be used as a CSO regulator. This is being demonstrated in Cleveland, Ohio and New York City, New York. The device is static, yet has the advantage over conventional static regulators in that it provides a relatively constant Q regardless of head.

### The Duck Bill Tide Gate

Tide gates are employed to protect collector sewers and interceptors from the inflow of tidal or high river waters. Without such control devices, backflows would surcharge collector sewers (causing flood condition), interceptors, pumping stations and treatment plants and adversely affect treatment processes and the capacity of drainage systems.

There are severe problems with the types of tide or flood gates currently in use, such as failure to close tight (because of debris blockages, warpage, and corrosion), a tendency to get stuck in one position and the need for constant regular maintenance. However, maintenance is expensive and time consuming, and there is a genuine need for a new type of tide gate not prone to all these problems described.

A demonstration was carried out in New York City to evaluate a rubber "duck-bill" tide gate (**Fig. 5**) in a combined sewer outfall. It is a totally passive device and requires no outside energy source. It appeared to be virtually maintenance free, yet sealed tightly around large solid objects. ■